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LIFT-AND-STRIKE WELDING PROCESS WITH CLEANING STAGE

The invention relates to a lift-and-strike welding process as well as to a lift-and-strike welding apparatus. The process and the apparatus are suitable in particular for welding a weld stud onto an aluminium surface or steel sheet surface, which have in each case a surface coating, e.g. a lubricant coating.

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A lift-and-strike welding process, in particular a stud lift-and-strike welding process, has the advantage of industrial-scale capability combined with processing reliability with regard to, for example, reliable ignition of an arc. The lift-and-strike welding process is also less noisy than other welding processes. The lift-and-strike welding process is therefore used in numerous fields especially on account of its being economical to operate. Especially in the automobile industry, lift-and-strike welding has become an established technique. Aluminium and aluminium composite components are becoming increasingly popular as materials in the automobile industry on account of their low weight. From DE 195 244 90, for example, a lift-and-strike welding process is known, wherein an aluminium weld stud is welded to a workpiece made of aluminium. According to said process, a height of lift of the weld stud is varied in dependence upon a measured arc voltage. It is also known from said document that, to prevent a short-circuit being caused by melted material dripping from the weld stud, a polarity at the weld stud or at the workpiece is reversed during the welding operation. It is also known that, by reversing the polarity, a formation of a molten bath is varied.

The object of the present invention is therefore to provide a lift-and-strike welding process and a corresponding lift-and-strike welding apparatus, with which an element may be welded reliably and with a high quality onto a surface, even if a coating should be disposed on the surface.

Said object is achieved by a first lift-and-strike welding process having the features of claim 1 as well as by a second lift-and-strike welding process having the features of claim 7, by a lift-and-strike welding apparatus having the features of claim 15 as well as

by means of a polarity reversing means having the features of claim 20. Advantageous developments and refinements are indicated in the dependent claims.

A first lift-and-strike welding process is such that, as a first step, a surface of a component is cleaned, namely by applying a first voltage so as to strike an arc between an element to be connected to the surface, in particular a stud, and the surface. In a second step, a polarity of the first voltage is reversed. Then the element is welded on by means of at least one second voltage.

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Said process is particularly suitable for use with steel sheets and aluminium sheets, which have an organic coating or are zinc-coated. The zinc coating may be electro-plated or galvanised or may be Bonazink. The coating may also consist of accumulated dirt or the like. For example, it has proved particularly suitable to use the process for the welding of steel sheets having a sheet thickness of 1 to 0.5 mm and less which has a zinc protection layer, e.g. in the case of hot galvanising, of 70 µm and less, e.g. also in the case of thin zinc protection layers, of 30 to 3 µm or even less. The cleaning process is very precisely adaptable to the surface to be cleaned and is also suitable for very thin coatings. There now follows a detailed description of the mode of operation of the invention with reference to a machining of a component made of aluminium. The features described below are however also applicable to the welding of a corresponding steel component, in particular a steel sheet.

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Aluminium components which are cold formed, in particular deep drawn, have a surface coating in the form of a lubricant. Said lubricant prevents cold welding between the aluminium workpiece and a machining tool. The lubricant moreover reduces the friction force which arises. An organic coating, in particular a wax or oil-based coating is often used. By striking an arc as a cleaning arc, the effect is achieved that the organically based coating as a result of overheating by the arc volatilises leaving no significant residues, in particular leaving no residue, and/or is displaced from the welding region. The subsequent actual welding operation by means of e.g. a pilot current and subsequent welding current of the lift-and-strike welding process allows the element, which is to be

INS B4

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welded on to be dipped into a weld pool of the aluminium surface which is not contaminated with the previous coating.

For cold-formed aluminium sheets a wax-based lubricant coating is customary. During an arc welding process, the wax releases hydrogen which would bond with the molten aluminium during the welding operation. The moment the molten aluminium hardens again, the ability of the aluminium to bond with the released hydrogen is lost. The hydrogen is exhaled and leaves behind a high porosity in the region of the joint zone. Said porosity leads to an enormous deterioration of the welding quality. Through use of the aluminium lift-and-strike welding process it is possible to avoid a poor welding quality. The process also allows its users to dispense with previous cleaning of the aluminium components used. Cold deep-drawn sheets, for example, prior to subsequent welding previously had to be sent through a washing lane in order to prepare the surface of the aluminium sheets for the welding process. Said cleaning operation is now no longer necessary. As a result, aluminium-containing components having a coating may even without basic preliminary cleaning be reliably welded e.g. with a weld stud. The quality of the weld joint therefore depends on the ambient conditions in the joint zone which are created by the cleaning arc, wherein the surface is advantageously rendered dry and metallically pure.

It is advantageous when, after the first step of applying the cleaning voltage, in a second step a polarity of the first voltage is reversed. By said means the cleaning may be influenced by altering the arc. It is further advantageous when, after the first voltage used as a cleaning voltage has dropped, the actual lift-and-strike welding process ensues after a specific period of time. The process is improved by reversing the polarity between the first and subsequent second voltage. Said reversal is effected preferably in the period of time, during which the first voltage has dropped, in particular to zero. In said case, during the cleaning phase a positive polarity is preferably adjusted for the first voltage. This means that at the aluminium surface of the component there is a negative potential, while the weld-on element has a positive potential. It is therefore possible to heat the aluminium sheet up to temperatures at which the coating is volatilised. The aim is in particular to clean a region of the surface which, for example, approximately

corresponds to, or is optionally slightly smaller or slightly larger than, the subsequent joint zone. Given use of a weld stud, the aim is to achieve a circular cleaned surface having a diameter which preferably corresponds to the diameter of the weld stud. Given a different geometry of the weld-on component, e.g. an oval or angular cross section, the cleaned surface is advantageously of a corresponding sise. This is assisted by a polarity of the type described above. For the subsequent welding operation a negative polarity is preferably selected. A negative polarity during the cleaning operation might give rise to the problem of rust particles arising and/or remaining in the region of the surface to be cleaned.

The first voltage is moreover preferably set higher, in terms of its magnitude, than the immediately following voltage of reverse polarity. It is set, for example, by appropriate adjustment of the height to which the weld-on element is lifted above the surface. By increasing the distance, the voltage may likewise be increased while the current intensity, for example, remains constant. This enables a requisite energy density to be produced for the cleaning operation while, e.g. given use of a subsequent pilot current for the lift-and-strike welding process with reverse polarity, the aluminium surface is heated up and the arc stabilised in such a way that a weld pool of suitably required depth is produced when the subsequent welding voltage is applied.

The application of a first cleaning voltage may be effected separately from a subsequent application of a pilot welding voltage. For reversal of the polarity of the arc, it is advantageous when the polarity is reversed when the first voltage reaches a zero value. For said purpose, the zero value is advantageously maintained for a short time. Said voltage-free time is provided, for example, when the weld-on element is being moved in the direction of the surface. It is only after said time that a second voltage, e.g. a pilot voltage, is built up. For said purpose, the weld-on element is situated, after the cleaning operation, back in contact with the surface. By lifting the element off the surface, the welding arc e.g. in the form of a pilot arc is then ignited. Said machining steps are however preferably combined with one another. As a result, the machining time of a component is reduced. According to a development, said time reduction is achieved in that a drop of the first voltage is immediately followed by the welding process

preferably using a pilot voltage and subsequent welding voltage, wherein the last two voltages have a different polarity to the first voltage. In said manner, a reliable ignition of the arc after the polarity reversal is possible.

The possibility moreover exists of applying the welding voltage directly after the first voltage and the subsequent polarity reversal.

A second aluminium lift-and-strike welding process is further provided. Said process may, for example, be combined with the first aluminium lift-and-strike welding process. The second aluminium lift-and-strike welding process comprises the following steps:

- an electric cleaning current flows between an aluminium surface of a component and an element to be welded thereon, in that the component rests on the aluminium surface and then the element is lifted off the aluminium surface up to an approximately, in terms of time, constant distance for removing a coating from the aluminium surface through ignition of an arc as a cleaning agent,

- then the current changes its polarity, wherein afterwards at least one welding current is produced and

- then the element is welded to the aluminium surface.

The particular effect realised with said process is that during reversal of the polarity the current continues to flow between the surface and the element to such an extent that, despite the polarity reversal, the arc does not collapse. The element need not therefore be brought back into contact with the surface for ignition of the arc.

Preferably a cleaning current is used, which assumes a current intensity of between 15 and 120 amperes, in particular 500 amperes, before it drops. Said cleaning current intensity is sufficient for complete removal of the coating, which is situated e.g. on one aluminium surface, by means of the arc. In said case, the duration of the cleaning

operation may be influenced by the level of the current intensity: the higher the arc current, the shorter the duration of the cleaning operation. The cleaning current intensity is however preferably set low enough to prevent a weld pool area from starting to form on the aluminium surface. The temperature is taken into account in such a way that there is, in particular, not yet any melting of material during the cleaning operation. This is simultaneously regulated or controlled e.g. likewise by the duration of the effective cleaning current intensity. It has moreover proved advantageous when after a reversal of the polarity an, in terms of its magnitude, maximum current is produced. Said current is then the welding current which ensures the formation at the aluminium surface of a weld pool of corresponding molten material, into which the element to be connected, e.g. an aluminium stud with a melted end face, is subsequently dipped. Preferably, the element is brought back into contact with the aluminium surface only after disconnection of the welding current. In particular, such a time delay is observed, that the weld pool has become doughy again but nevertheless still retains its bonding capacity.

According to a development of the aluminium lift-and-strike welding process, the cleaning current lasts approximately as long as or longer, in particular at least 3 times longer, than a pilot current flowing prior to the welding current. It is further advantageous when the welding current is equal to or stronger, in particular at least 1.2 times stronger, than the cleaning current. The injection of power into the workpiece achieved in each case thereby is therefore appropriate to the respective objectives of the individual process steps. The maximum power injection is effected during the actual welding operation and a power injection for cleaning purposes, which is adapted to the respective coating of the aluminium surface, is accordingly lower.

The nature of the power injection may moreover also be regulated by means of the duration. This is dependent, on the one hand, upon the type of coating and, on the other hand, upon the thickness of the coating. In particular, the volatilising of the coating is recorded by a suitable apparatus and used as the basis for adjusting, e.g. regulating or controlling, a power injection by means of the cleaning current or the cleaning voltage. This also enables later evaluation of corresponding parameters of the cleaning operation for a subsequent quality inspection, e.g. while also taking into account parameters of the

subsequent welding operation. Volatilising of the coating is measurable, for example, through a variation of the arc voltage or the current. Through measurement of a suitable parameter, the duration of the cleaning step may also be regulated so that, given a corresponding variation of the measured value, e.g. of the voltage, the cleaning operation is terminated, the polarity is reversed and the welding process ensues. When, for example, the surface is being cleaned to remove an organic coating containing hydrogen, a voltage drop of the arc voltage is to be observed once the hydrogen, which is to be removed, has been removed. A corresponding lift-and-strike welding apparatus therefore comprises, for example, a suitable measuring, regulating and/or control device which provides appropriate functions. Such an apparatus also comprises a suitable evaluation device e.g. with a suitable memory etc.

It has further proved advantageous when the element, during cleaning of the aluminium surface, assumes a distance from the aluminium surface which is at least 2 times greater than the distance from the aluminium surface particularly when a pilot current flows prior to the welding current. It is therefore possible, on the one hand, to clean a larger area of the aluminium surface. On the other hand, the possibility exists of using a variation of the distance to adapt the intensity of the cleaning in accordance with the respective coating without having a negative effect upon the base material.

INS B5

Besides the previously described features, the measures for controlling and/or regulating the weld stud which are known from DE 195 244 90 are moreover also applicable for effecting the aluminium lift-and-strike welding process. In particular, it has proved advantageous to use, for welding-on, stud geometries of the type disclosed in DE 196 11 711. Express reference is hereby made to the respective technical teaching of both documents.

INS B6

An aluminium lift-and-strike welding apparatus is further provided. The apparatus comprises a guide for a weld-on element and a control device for the guide. The guide is, for example, a welding head, a welding gun or a housing for fixing and lifting the weld-on element. The apparatus further comprises a device for controlling or regulating the electric current and/or the voltage used for welding, wherein the apparatus has a polarity

B6 Cont'd

reversing means for the voltage used for welding. The device for controlling or regulating the electric current and/or the voltage is programmed or designed so as to produce, prior to the welding operation, a cleaning current which has a reverse polarity relative to the welding current. The apparatus may be used in particular to effect a process in accordance with the above description.

The invention further provides a polarity reversing means for a lift-and-strike welding apparatus, The polarity reversing means comprises a circuit element which produces an arc current during the reversal of the polarity, in particular in the form of a circuit acting as a reactor in order to maintain a struck arc during a reversal of the polarity of the arc voltage. The polarity reversing means advantageously comprises a first and a second power source, wherein the first power source supplies a cleaning current and the second power source supplies a welding current. A coil is advantageously connected to the first and the second power source in such a way that a struck arc continues to be maintained during reversal of the polarity. An extinction of the arc is therefore prevented when the current passes through zero.

Further advantageous refinements and developments as well as features of the invention are illustrated in greater detail in the following drawings, in which:

Fig. 1 shows a characteristic of a distance S and of an electric cleaning current I in a first step of the lift-and-strike welding process,

Fig. 2 shows the characteristic of the distance S and of the electric current I in a welding step as a third step of the process,

Fig. 3 shows a development in the form of a combination of the first step, a second step and the third step,

Fig. ~~4 shows~~ an apparatus for implementing the process,

Fig. 5 shows a sketch of the apparatus for implementing the process,

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Fig. 6 shows a circuit diagram of a polarity reversing means and

Fig. 7 shows a stud welded on a sheet having a coating.

Fig. 1 is a diagram illustrating a possible first step as a cleaning step of the process sequence of the welding process. A current intensity I and a distance S are plotted along the y-axis. The distance S is the distance between the weld-on element and an exemplary aluminium surface. The time coordinate is plotted along the x-axis. In the first step, the weld-on element is situated in contact with the aluminium surface. The current intensity I is switched on. A flow of current occurs between aluminium surface and the element. The cleaning current being injected is preferably adjusted to a magnitude of between 20 and 500 amperes. Said cleaning intensity is preferably held approximately constant also for a specific period of time. After a short time delay after switching on the current intensity I, the element is lifted off the aluminium surface and preferably moved up to an approximately constant distance S. The cleaning current intensity is kept constant and the arc voltage arises in accordance with the distance S and the degree of cleaning. The distance S is advantageously approximately 3 mm for an aluminium weld stud. After a duration Δt, which starts with lifting of the element from the aluminium surface and ends with the dropping of the cleaning current intensity to zero ampere, the aluminium surface is cleaned. The duration Δt is preferably set between 15 ms and 120 ms. The advantage of said cleaning is that the cleaned area remains limited at least to approximately the weld pool area subsequently required. When, for example, there is provided on the aluminium surface a coating which is to be retained also in the subsequent workpiece, e.g. a protective coating, the process offers the advantage of having removed the coating only in the region of the welding zone. The distance S is in particular adjusted in such a way that the arc which arises is focused on the aluminium surface and so the surface to be cleaned remains limited. Preferably, such a focusing of the arc is adjusted by means of a suitable guide for the weld-on element. Alternatively, the welding apparatus may have a suitable focusing device which is, for example, integrated with the guide. According to one construction of a suitable welding apparatus, use is made for said purpose of a guide comprising a collet, around which an a.c.-operated magnet coil is

disposed. By said means it is possible to prevent a dispersion of the arc as a result of blowout. The first step is followed by the polarity reversal as a second step, which is not shown in detail.

Fig. 2 shows a third step of the process which comes after the first step of Fig. 1 and the second step, namely the subsequent polarity reversal. The polarity reversal is evident from the change of the sign of the current intensity. Preferably, a change from positive to negative occurs. According to a development, the weld-on element remains in the lifted position, e.g. 3 mm up, for a specific period of time. This allows any material of the aluminium surface and also possibly of the surface of the element itself which has already melted to harden again. For example, 10 to 80 ms, preferably up to 30 ms after disconnection of the current intensity, the lift e.g. by means of a coil is switched off and the element comes back into contact with the aluminium surface. From said point on, the third step in Fig. 2 begins. Reversal of the polarity from positive to negative in the second step is followed by the start of a lift-and-strike welding process of the type disclosed e.g. also by the already cited DE 195 244 90. For example, an arc is ignited by a pilot current, which provides for a stabilising of the welding current. For said purpose the weld-on element, which has been back in contact with the aluminium surface, is removed once more from the surface. According to the diagrammatic embodiment, the distance S then remains once more substantially constant. After a specific period, which lasts longer than the actual welding current duration, the pilot current is increased to a welding current, e.g. to 1000 amperes or more. During application of the welding current, the aluminium surface is melted to such an extent that an adequate pool depth is provided. After the welding current has dropped to 0 ampere, there is additionally a specific waiting period to allow the aluminium pool to become doughy. Only then is the element to be welded dipped into the surface and the weld joint produced. An implementation of the process in the manner shown in Fig. 1 and Fig. 2 has the advantage of a precisely predetermined pattern. By linking the steps to one another, the machining time is simply added up. This may lead to somewhat longer retention times in the machining station, e.g. of 300 ms and more. Said time is also dependent *inter alia* upon how much time the reversal of the polarity takes. The reversal preferably takes no longer than 200 ms. A development therefore provides that the first step of Fig. 1 and the

third step of Fig. 2 be combined with one another. This is explained in greater detail below.

Fig. 3 shows a combination of the first, second and third steps of Fig. 1 and Fig. 2 in the form of a combination of the process steps without contact of the weld-on element between cleaning and welding. A reversal of the polarity of the current is effected without the weld-on element in the meantime coming into contact with the aluminium surface. Rather, the cleaning current I is converted by reversal of the polarity into a pilot current of the welding process. Said reversal is effected by suitable adaptation of the decrease of the cleaning current intensity up to the passage through zero. After the passage through zero, the current intensity with a negative polarity, indicated by the minus sign in Fig. 3, is controlled or adjusted to a suitable current magnitude of a pilot current. Then the maximum welding current ensues. Compared to the individual steps as they emerge from Fig. 1 and Fig. 2, the machining time is only an insignificant amount, e.g. about 100 ms, longer than a conventional lift-and-strike welding process.

Tests have shown that, with the following values, particularly good welding results have been achieved for an aluminium surface in combination with an aluminium stud:

cleaning current intensity:	15-500 amperes
cleaning period:	20-100 ms
distance S for duration of cleaning	2.5-3.5 mm
pilot current intensity:	15-25 amperes
duration of pilot current intensity:	0-8 ms
distance S for duration of pilot current:	0.6-1.4 mm
welding current intensity:	500-1500 amperes
duration of welding current:	8-100 ms
distance S for duration of welding current:	1.4 down to 0.6 mm

Fig. 4 shows the diagrammatic view of an apparatus 1 for implementing the lift-and-strike welding process. The apparatus 1 comprises a collet 2, around which a coil 3 is disposed. By means of the collet 2 a weld-on element 4, in the present case an

aluminium weld stud, is guided onto an aluminium surface 5 of an aluminium sheet 6. During the welding operation an inert gas, e.g. argon, flows around the element 4. The inert gas is indicated by the arrows 7 which surround the element 4. Alternating current flows through the coil 3. The alternating current is controlled and/or regulated so that it influences the arc and the arc shape in such a way that the coating 8 on the aluminium surface 5 is removed only in the region where a welding with the element 4 also later occurs. The coil 3 is preferably operated with an alternating current of between 8 and 30 volts. A current intensity of between 0.1 and 2 amperes is advantageously used. The number of turns as well as the cross section of the coil turn are material-dependent. The coil is in particular selected so as to be capable of bringing the arc very close in to the axial magnetic field and not into the stray field. The stray field would produce a rotating arc, while the axial magnetic field is capable of focusing the arc symmetrically around the axial axis of the stud.

Fig. 5 shows a diagrammatic view of the lift-and-strike welding apparatus. By means of a guide 9 a weld-on element (not shown in detail) may be guided onto an aluminium component (not shown). The apparatus further comprises a control device 10 or regulator for the guide 9. The apparatus 1 likewise comprises a device 11 for controlling or regulating the electric current and/or the voltage used for welding as well as a polarity reversing means 12 constructed e.g. by means of thyristors. The device 11 is programmed or operated in such a way as to produce, prior to a welding operation, a cleaning current which has a reverse polarity compared to the welding current. The reversal of the polarity is effected by means of the polarity reversing means 12. The lift-and-strike welding apparatus 1 may be used in particular to produce an aluminium surface with a welded-on element, wherein the aluminium surface has or has had a coating, in particular a lubricant coating.

Fig. 6 shows an exemplary circuit diagram of a polarity reversing means 12. A first 13 and a second 14 power source are connected in parallel. Both power sources 13, 14 here are constant-current sources. The first power source 13 supplies a current for cleaning and builds up a positive polarity: whereas the stud has a positive potential, the sheet 6 has a negative potential. This is indicated by the plus sign. The second power

source 14 supplies a current for the welding step and hence for the pilot current and the actual welding current. The second power source 14 comprises a shorted circuit, which is activated by a closed switch S2. When the polarity reversal is initiated, the second power source 14 operates in the short circuit and injects a current into a reactor 15. The cleaning current produced by the first power source 13 is then reduced towards zero. Before the cleaning current reaches zero, the shorted circuit switch S2 is opened and the welding circuit switch S1 is closed. The injected current in reactor 15 flows into the welding circuit. It prevents extinction of the arc when the current passes through zero. The switch S3 is opened and the first power source 13 is decoupled from the welding circuit.

Fig. 7, in a view corresponding to Fig. 4, shows a stud 4 now welded on a sheet 6 having a coating 8 on the surface. In the region of a joint zone 16 the coating 8 is no longer provided. It has been removed during the cleaning step in the region of connection of the stud 4 and the sheet 6 in accordance with the adjustment of the arc. The process is therefore also particularly suitable for producing a steel sheet with a welded-on element, wherein the steel sheet surface has or has had a coating, in particular a lubricant layer or a zinc layer.

INS B8